Ratio Working Paper No. 18

Property Rights and Economic Growth

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PROPERTY RIGHTS AND ECONOMIC GROWTH

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This paper was prepared for presentation, on January 15, 2003, at a conference sponsored by the Gosta Bohman Foundation, to take place at the Riksdag (Parliament) Building in Stockholm, and for a seminar arranged jointly by the Ratio Institute and the Stockholm Chamber of Commerce, on January 16.

My main purpose today is to connect the issue of property rights to the set of questions concerning economic growth and the long-term determinants of the improvements in material well-being. To anticipate what will be my main conclusion, it is that property rights and economic growth are not separable. But that statement, by itself, is not very interesting. What is important is not my eventual conclusion but how I come to arrive at that conclusion. And I should warn you in advance that I will arrive at that conclusion via an unconventional pathway, and that our guide along that pathway - at least our initial guide - will be Karl Marx.

Shortly after the collapse of the Soviet Union at the beginning of the 1990s, I wrote an article for the Scientific American about the connection - or rather about the **lack** of connection - between Marx's writings and the collapse of the Soviet Union. My main point was that, in Marx's view, true socialism could arise as a viable form of economic organization only after capitalism had worked its unique magic; only after capitalism had created a highly productive society that only capitalist institutions and incentives were capable of providing. I received a flood of mail - much of which I can only call "crank mail" - from people who were quite insistent that Marx was all wrong. It turned out that someone in the editorial office of Scientific American had given my article the title "Marx Wasn't All Wrong," which was very much in the spirit of what I had written. But, for many readers, even that seemingly innocuous title was too much of a concession. Marx had to be **all** wrong. Let me simply say that it is most unlikely for a person who has written so many thousands of pages, as Marx had, to be all wrong. He was, in fact, right about some quite important matters.

Writing in the middle of the 19th century and looking back, as a historian, upon the immense improvements in human productivity that were the central achievement of the industrial revolution, Marx emphasized one central point: His point was not that those achievements were due to human ingenuity, or to the earlier scientific revolution, or to a work ethic that was inspired by the Protestant Reformation. No. His main point was that this outburst of human ingenuity and creativity was the work of the capitalist, or rather, to use his term, the bourgeoisie. This is certainly his central point in the opening half dozen pages of the Communist Manifesto. (1848). In a word, the historic accomplishments of capitalism were due to its unique ability to generate technical change. Capitalist societies, **unlike** all earlier societies, provide powerful incentives for the generation and the utilization of new technologies:

"The bourgeoisie cannot exist without constantly revolutionising the instruments of production...Conservation of the old modes of production in unaltered form was, on the contrary, the first condition of existence for all earlier industrial classes..."

“The bourgeoisie has...been the first to show what man’s activity can bring about. It has accomplished wonders far surpassing Egyptian pyramids, Roman aqueducts, and Gothic cathedrals...”

In an even more extravagant later passage, Marx and Engels assert: “The bourgeoisie, during its rule of scarce one hundred years, has created more colossal productive forces than have all preceding generations together. Subjection of Nature’s forces to man, machinery, application of chemistry to industry and agriculture, steam-navigation, railways, electric telegraphs, clearing of whole continents for cultivation, canalisation of rivers, whole populations conjured out of the ground - what earlier century had even a presentiment that such productive forces slumbered in the lap of social labor?” I should state that I am in full agreement with each of the quotations from Marx that I have just cited. Marx wasn’t all wrong.

As I see it, however, Marx overlooked 2 very important points:

1. That the act of introducing a drastically new technology, which has been the primary source of long-term economic improvements, is full of uncertainties, uncertainties that render investment in new technologies a highly risky financial undertaking.

2. That the success of capitalism was primarily due to legal, institutional and regulatory changes that, in many instances, amounted to significant redefinitions of the rights attached to property. Indeed, I would argue that these redefinitions amounted, in many cases, to legal and institutional innovations of tremendous social significance. The cumulative effect of such innovations has been to reduce the intolerable financial risks that had been associated with the introduction of new technologies. As a consequence, such risks were by no means eliminated, but they were reduced to more acceptable levels. I don’t know, for example, if there were debtors’ prisons in Sweden in the 18th century, but I can assure you that such prisons existed in England at that time. Adam Smith expressed well the contemporary British view in his Wealth of Nations, published in 1776: “Bankruptcy is perhaps the greatest and most humiliating calamity which can befal an innocent man. The greater part of men, therefore, are sufficiently careful to avoid it. Some, indeed, do not avoid it; as some do not avoid the gallows.”

I would like, then, to focus first on the high risks of innovation. One of the central reasons that we do not fully appreciate the risk of failure in technological innovation is that the history books dwell upon the success stories, not the failures. Success stories, after all, are so much more interesting, and we hope that they serve as sources of inspiration to the young. The success stories have, in a sense, happy endings, and they are full of consequences for the future in a way that is not true of failures. The result is that the history of industrialization is typically told in terms of a series of success stories. In Anglo-American school textbooks we find something like this: In the beginning was James Watt (or, just possibly, Thomas Newcomen), Henry Cort, Josiah Wedgwood, Richard Arkwright, Eli Whitney, Robert Fulton, Thomas Edison, The Wright Brothers, etc. There is some analogy here with military history where, as it has been said, history is written by the victors, not by the vanquished.

But in spite of the neglect of failures in our history books, when one digs a bit deeper one finds that the risks of business failure were immense. A doctoral dissertation at LSE some years ago, drawing upon court records, found that there were no less than 33,000 business failures leading to bankruptcies in England in the course of the eighteenth century. This huge number, in what was still a small country, included business failures of all kinds, not only those specifically connected with new technologies. But of particular interest from my present perspective is the fact that the frequency of business failures experienced a sharp acceleration after 1750, coinciding exactly with the rise in technological innovation that we later came to call the industrial revolution. Post-1750 is also precisely the period that Marx had in mind when he wrote, in 1848, that “The bourgeoisie, during its rule of scarce one hundred years, has created more colossal productive forces than have all previous generations together...” Here again, Marx was right, although in 1848 he failed to call attention to the very high incidence of commercial failures connected with technological change; at least he failed to do so in the Communist Manifesto and in his enormously influential first volume of Das Kapital (1867).

Yet it is of considerable interest to note that Marx himself did eventually recognize this uncertainty, although the recognition only made a much-belated, and obscure, public appearance in the third volume of Capital, published after his death, and many years after the publication of volume I. In the third volume Marx called attention to “the far greater cost of operating an establishment based on a new invention as compared to later establishments arising ex suis ossibus. This is so very true that trail-blazers generally go bankrupt, and only those who later buy the buildings, machinery, etc., at a cheaper price make money out of it.” This is a most interesting passage, since it constitutes explicit recognition on Marx’s part of the extreme

vulnerability of the capitalist in his social role as a carrier of technical change ("trail-blazers generally go bankrupt."). Had Marx given more attention to this vulnerability in volume I of Capital, it would have been necessary to portray the capitalist in a distinctly different light. Indeed, it would have been necessary to write an altogether different book. This observation would have highlighted the weakness of capitalists, whereas Marx was intent, in volume I, on portraying their social power and their consequent capacity for exploiting others.

II

Suppose we now focus on financial risk in the contemporary context, where much of the scientific and engineering research of OECD member countries has been institutionalized in large industrial firms, and labelled Research and Development (R&D). In the US today there are reported to be more than 16,000 industrial laboratories, and it is also reported that more than 20 of these firms have R&D budgets of more than $1 billion per year. The top 20 US industrial firms, when these firms are ranked by R&D spending, spent a total of $54 billion on R&D [in the year 2000]. Surely it is reasonable to assume, as some have argued, that these powerful, affluent organizations have largely or completely eliminated financial risk. Such an assumption would, of course, be very far from reality. Huge financial risk continues to come from many possible sources: What are these sources?

1. Expenditures on research may simply fail to discover new scientific knowledge of any potential usefulness whatever.

2. Even if new scientific knowledge does emerge from research at the scientific frontier, it may never lead to a new marketable product. Or, it may require such a long period of expenditures on new product design or development that business decisionmakers may conclude that the new product is simply too costly.

But even if research does eventually lead to a new, valuable product concept, many further questions remain to be addressed:

3. How well will the new product perform technologically? Will its high performance be possible only at a prohibitively high cost? The Concorde airplane was a magnificent achievement in terms of engineering design and speed, but it was also an unqualified financial disaster (It was a financial disaster that was mainly financed, in this case, by the taxpayers of Britain and France).

4. How rapidly will performance improve and how rapidly is the cost of production likely to decline?

5. How attractive will the new product be to the consuming public? How elastic (or inelastic) is the demand for the product likely to be, and at what price ought it be introduced into the market place?

6. How appropriable is the product for the innovating firm? By “appropriable” I mean, how great is the likelihood that the innovating firm will be able to capture any profits that might be generated by its innovation? This may depend on whether the innovation is patentable. If not patentable, how soon is it likely to be imitated by competing firms that spent none of their own money in inventing the product? [This is the “free rider problem”].

7. It is possible that a government regulatory agency, or a court decision, may destroy expected profits through regulatory requirements or a judicial ruling, given the extensive concerns over pollution of the environment, occupational safety or health? Health considerations have long been a major concern in the pharmaceutical industry. The US Food and Drug Administration requires that new pharmaceutical products go through a protracted period of testing before they may be sold to the public. Many new pharmaceutical products must be tested for several years before they can be marketed - in some cases the testing period may be more than a decade (as in the cases of vaccines or new contraceptive technologies). Estimates of the cost of bringing a wholly new pharmaceutical product to market in the US now routinely exceed the $500 million mark. Additionally, you are presumably all familiar with ABB’s financial collapse due to its earlier acquisition of Combustion Engineering. It turned out that ABB eventually “inherited” (if that is the right word) the huge liabilities of this subsidiary. These liabilities resulted from a court decision, in a gigantic class action suit, involving the potential damage to human health of Combustion Engineering’s extensive use of asbestos. The class action suit has already involved more than 200.000 claimants, with over 100,000 more claimants still to be dealt with (Only in America!).

8. How soon will a new and superior product come along, either from a competitor or from some totally new technology? It is no paradox to say that one of the greatest uncertainties confronting new technologies is the invention of still newer technologies.

For these, and other reasons, the central issue in the innovation process remains having to make major financial commitments in the face of numerous uncertainties. From the point of view of the potential entrepreneur, then, innovative activity continues to involve the assumption of large financial risks. Indeed, the size of these risks may well be growing in the contemporary world.

Much of what I have said so far has touched upon risks that are connected to the inability to forecast the possible outcomes of R&D projects. I believe that a large dose of humility is appropriate in this realm because, even when these research projects prove to be successful, it can be enormously difficult, especially in affluent societies, to forecast consumer reaction to the new product, and how it will fit in with consumer preferences and priorities. Consider the following episode: In 1939 the New York Times, the staff of which has certainly consisted of reasonably intelligent and perceptive people, reported on the success of recent experiments that clearly foretold the arrival of a potentially fascinating new product: television. But the New York Times' staff did not believe that television had much of a future - at least not in the US. Rather, this most prominent and reliable of all American newspapers solemnly intoned: "Television will never be a serious competitor for radio, because people must sit and keep their eyes glued on a screen; the average American family hasn't time for it." I am inclined to say that no further comment on that particular forecast seems necessary, except to add that a great many American families seem - sadly - to have little time for anything else. How can you explain what seems so painfully obvious to us in retrospect: the total failure to anticipate that TV was to become the most widely-used and influential consumer good of the twentieth century? Frankly, I don't know how to answer that question, and I only want to add that there have been many similar experiences of failure to forecast the large future impact of some recent invention - in this case, to underestimate demand rather than to underestimate costs or the postponement of revenue flows.

Consider a more recent innovation: the mobile phone, a product in which Sweden has played a large, pioneering role. In 1983, when AT&T was in the process of being divested, it was considering the possibility of entering into the production and sale of this new form of telephony. AT&T hired one of America's best-known consulting firms to forecast how many American subscribers for mobile phones there would be likely to be by the year 1999. The forecast that was given to AT&T was that there might be as many as one million subscribers to such phones in 1999. In fact, the number of subscribers passed the 70 **million** mark in that year! [See Jerry Hausman**, "**The Cellular Telephone, New Products and the CPI," NBER Working Paper 5982. For an extensive treatment of the Swedish experience, which includes

some parallel experiences, see Sven Lindmark, “Evolution of Techno-Economic Systems - An Investigation of the History of Mobile Communications,” doctoral dissertation, Chalmers University, Goteborg, 2002].

How can you account for what now appears to have been an absurd underestimate? Partly, of course, there was a failure to appreciate the large number of ways in which such phones would be useful. But the underestimate was also caused by neglect of another consideration that is widespread in anticipating the future demand for innovations. The fact is that most new innovations enter the world in very primitive conditions, and go through a long process of technical improvement and cost reduction before they become marketable on a large scale. The airplane first left the ground in 1903 but was not a major **commercial** product until the late 1930s. It required fully one-third of a century because many thousands of design improvements were necessary before airplanes became sufficiently safe, reliable, comfortable and cheap to become widely used by the general public.

The situation with respect to the mobile phone of 1983 was also quite similar. Those phones were primitive. They were so heavy and bulky that they hardly deserved to have been called “mobile.” Indeed, the very first mobile phones were installed in vehicles. The quality of voice transmission was extremely poor. And, most important, the original mobile phones of 1983 sold for more than $3000 in the U.S. This compares with much less than $100 in the US today. Indeed, in some cases today the phone is given away free of charge, but the recipient of such a phone would be well advised to read the fine print in the subscribership contract very carefully. (At least in America).

Even when future demand is drastically underestimated, as in the cases of TV and mobile phones, the costs incurred in the R&D that is eventually required to prepare the new product for market are likely to be highly uncertain, and also very great. This throws us back to the considerations just enumerated. I.e., we do not get away from high uncertainty.

But the uncertainties to which I have been calling your attention, in the instances of TV and the mobile phone, are both cases where the technological innovations **already existed**, albeit in rather primitive forms. In such cases, at least, the general direction or trajectory of future R&D is reasonably well defined. When we consider expenditures on fundamental scientific research, the uncertainties are immeasurably greater, because basic research is usually understood to mean thatit is undertaken with no particular useful goal in mind. Consider the discovery of the laser, for which 3

scientists, 2 Russians and an American, shared a Nobel prize in 1964, although Einstein had already predicted the phenomenon, on purely theoretical grounds, as long ago as 1917. The laser has exercised a direct impact on an enormous range of activities and products. Consider:

1. The laser has become a primary instrument of scientific and engineering research due to its ability to perform operations and measurements with a degree of precision that was previously impossible. Lasers are now being used to probe, to measure and to modify the fundamental properties of matter in the realms of chemistry, biology and physics. Aeronautical engineers now use laser beams to measure such things as local flow velocity and turbulence in the design of aircraft during experimentation with new designs in wind tunnels. Several Nobel prizes in science have already been won for basic research that made extensive use of lasers.

2. In addition to their role in medical research, lasers have become the instrument of choice in a range of surgical procedures. These include a wide variety of extremely delicate operations upon the eye, such as the repair of detached retinas, which can cause blindness, and reshaping of the cornea in order to correct nearsightedness. My ophthalmology clinic in Palo Alto now has a separate section called the “Laser Center.” In gynecological surgery, lasers now provide a simpler and less painful method for removal of certain tumors. Lasers are presently being tested for the treatment of enlarged prostate glands. The US Food and Drug Administration has recently approved the use of a laser treatment for back pain. Lasers have also received FDA approval for the removal of unwanted body hair and, much more important, as a substitute for the dentist’s drill. An impressive index of the impact of the laser in medicine is that there are now five journals in the US, established since 1980, that are devoted **exclusively** to the application of lasers in medicine.

3. The laser has become a multipurpose tool in industry. In textiles it is used to cut cloth to desired shapes, and it is employed for similar uses across many metallurgical sectors, as well as for cutting complex patterns in such materials as plywood, glass and plastics. The Gillette Corporation advertises that their razor blades are now welded by laser. In food processing, lasers are being used, so far only experimentally, to identify contaminated meat.

4. The most successful computer printers are now based upon laser technology. The manuscript on which this talk was prepared is the product

of a Hewlett-Packard laser-jet printer. Lasers are also now widely used in the related activities of typesetting, newspaper plate making and the printing industry more generally.

5. Lasers are now the basic technology inside the bar code scanners at checkout counters in supermarkets, as well as in libraries, in inventory control technologies, and in security devices in department stores.

6. Lasers are now the technology of choice for the high quality reproduction of music in compact discs.

7. The military applications of the laser are fast multiplying. They are being used as triggers for nuclear bombs, and also for directing the so-called “smart bombs” and missiles to their targets. Lasers have also been widely touted as the key to the development of anti-missile devices, although there continues to be much disagreement on the potential effectiveness of this application. The Lawrence Livermore weapons laboratory in California recently reported that it had created a portable laser that can eliminate graffiti from walls at “lightning speed.” A cynical interpretation is that this is part of a move to protect their huge research budget by showing that their laser technology can also be applied to nonmilitary uses. Nevertheless, a device that could readily remove graffiti would be enthusiastically welcomed in many of the world’s large cities.

With respect to this extraordinary diversity of applications, let me suggest a simple thought experiment. Go back in your own minds to the early 1960s, after laser action had already been achieved, and ask yourself the following question: Which of the eventual uses of the laser that I have just enumerated do you think you would have forecast if you had been around at that time? And notice that I have not even mentioned the much more complicated case of telecommunications, where the use of the laser required the simultaneous development of another truly major complementary invention: optical fibers. The telecommunications revolution of recent years has been largely the product of the combination of these two inventions.

I would like to be the first to admit that I would not have forecast any of the applications that I have just mentioned. After all, what is a laser? A laser is basically no more than a special kind of light beam - a coherent light beam formed by the way atoms behave when they are subjected to certain high energy levels. But it is far from obvious that the deepest understanding of the pure science underlying the laser would lead anyone directly to the very different kinds of functions that are now

routinely performed by lasers. I should point out that some of the most capable patent lawyers in America also failed completely to anticipate the most commercially important impact of the laser - its impact upon the global telecommunication system. In the words of Charles Townes, who subsequently shared a Nobel Prize for his research on the laser: “Bell’s patent department at first refused to patent our amplifier or oscillator for optical frequencies because, it was explained, optical waves had never been of any importance to communications and hence the invention had little bearing on the Bell System interests.”

III

Now, in view of the often horrendous difficulties that are inevitably encountered in attempting to forecast where new technologies may be going, why would any sensible person, or any profit-making firm, ever be willing to commit sizeable financial resources to such obviously high-risk enterprises? An adequate answer to this question would involve an examination of at least four centuries of legal and institutional changes in capitalist societies in western Europe and North America [See Rosenberg and Birdzell, How the West Grew Rich]. I offer a two-pronged answer.

The first part of the answer is, in a sense, simple and straightforward. Capitalism is a form of economic organization that holds out the possibility of huge financial rewards to entrepreneurs who succeed. The second part of the answer is more complicated, but it reduces to something I have already been hinting at: western societies have introduced a number of political and legal innovations that have had the effect of substantially reducing certain kinds of uncertainties, or at least reducing the financial consequences of failure to much more tolerable dimensions.

In western Europe, after about 1600, a major source of uncertainty reduction came from changes in the political system. These changes had the effect of limiting the ability of rulers - kings or emperors, or their agents - from exercising their absolute political power in arbitrary, unpredictable ways. Some of this came earliest in England in the seventeenth century, with the introduction of an elected parliament in which property owners were represented and which eventually came to control the financial pursestrings of the nation. This meant that neither the king nor his agents could confiscate property or impose higher taxes at will. The nation’s budget came to be determined by taxes that were set by an elected parliament (Of course the voters were, at that time, exclusively property owners). Thus the taxes to be paid by business firms in the future were much more predictable, and business firms could

therefore make investments in innovation in full knowledge of what their tax liabilities would be - at least for some distance into the future. Taxes, then, became calculable - predictable - and therefore less subject to the uncertainty of unanticipated changes. [Chancellor Schroder].

To be predictable meant that someone who was familiar with the law, and legal precedents, could reasonably make plans about the investment of his capital without having to worry that some politically powerful person could, at some later stage, arbitrarily interfere with those plans and perhaps ruin them. Along with this was the establishment of commercial law courts for the enforcement of property rights and contractual agreements. These innovations in politics and law came to be referred to as providing “a government of laws and not of men.” They were of fundamental importance in societies that were making technological innovations that would often involve large financial commitments extending far into the future.

Within this larger framework, a number of other legal and organizational innovations were gradually introduced. These had the common effect of reducing the extent of the financial risks to which potential innovators would be exposed in market-oriented societies. Central, of course, was the legal concept of limited liability. The owners of shares of stock in the limited liability corporation could lose the entire value of that stock if the firm should accumulate huge debts that it was incapable of repaying,, but the owner of the shares of stock could not lose other assets Closely connected was the emergence of stock markets in which the owners of shares of corporate stock could quickly, and easily, dispose of these assets if they came to expect that the future of the business was likely to involve greater financial risks and/or lower prospective financial payoffs than was previously anticipated.

Perhaps the oldest significant commercial form of risk reduction was the role played by insurance companies. The earliest activities of insurance companies, especially in the form of maritime insurance, date back centuries before the rise of capitalist economies, but capitalism vastly increased the scale and the extent of specialized services provided
bys these institutions.

Later on, in the course of the nineteenth and twentieth centuries, futures markets were developed that would enable a business firm to fix a price today for the delivery of some asset (wheat, foreign exchange) at some specified time in the future. Futures markets thus enabled the firm to avoid the uncertainty of large future price increases that might endanger its financial future. Here again, although a certain risk

was avoided, the commitment also involved the “risk” that the firm would lose the opportunity to purchase the asset at a lower price in the event of an intervening fall in the price of that asset.

There have been various attempts on the part of policy makers to minimize the downside risks of corporate failures. In the US this took the form of the Bankruptcy Act of 1978. Chapter 11 of this Act included provisions that would reduce the cost of failures by rendering the consequences of bankruptcy less punitive and by making it easier for a firm to undertake reorganization, after filing for bankruptcy, rather than going directly into liquidation.

It is difficult to evaluate the success of this option, especially since it often involves retention of the same management that made the decisions leading to bankruptcy in the first place. In many cases there is at least a presumption that such management were poor decisionmakers, and allowing them to remain in place may provide such management with opportunities to further “strip” the firm of valuable remaining assets. The alternative, in many other countries, has often turned out to involve keeping the failed firm alive with substantial government subsidies. A better market-based alternative would involve reorganization with new leadership, along with new private investors who might be prepared to risk their own “new money” to rehabilitate a bankrupted company. Not surprisingly, such investors often fail to present themselves.

The most widely-used approach to risk reduction, employed at many levels and in many places, is the diversification of assets. Individuals and organizations may reduce their exposure to financial risk by diversifying the assets that they choose to buy and to hold in their investment portfolios, rather than owning, say, shares of stock in only a small number, or even a single firm. Mutual funds will happily make diversification selections for an individual investor - for a certain fee, of course. Maximizing the returns from an investment portfolio is an extremely complex and subtle analytical exercise, in view of the fact that higher expected financial returns typically involve taking greater risks. So subtle, in fact, that a Stanford University professor shared a Nobel Prize in economics in 1990 for developing a rigorous analytical method that distinguished between diversifiable and nondiversifiable risks. Appropriately enough, the professor’s name is “Sharpe.” [William F. Sharpe. Prize shared with Merton Miller and Harry Markowitz].

The same basic principle of risk reduction through portfolio diversification underlies one the most significant institutional innovations in recent decades: the venture capital industry. The great contribution of the venture capital industry was to become a source of capital to young, high-risk, high tech firms that were unable to borrow from banks because of insufficient collateral. In the US, where the venture capital industry has been most influential, the private venture capital industry emerged around 1980. This emergence was primarily the result of regulatory and legislative changes that, again, converted high risk but also high tech opportunities to more acceptable risk levels. This was achieved through portfolio diversification on the part of the venture capital firm and, at the same time, changes in the tax structure that offered improved prospective payoffs to successful entrepreneurship. The main changes were (1) reductions in the capital gains tax, (2) the deferral of tax liabilities for holders of stock options until the time when the stocks were sold rather than when the options were exercised, and (3) regulatory change (ERISA) that allowed pension funds to invest in high risk securities issued by small or new companies and venture capital funds. These changes essentially opened up a floodgate of investment funds through the 1980s and 1990s, most especially in computer hardware and software, medical and biotechnology sectors, communications and semiconductors..

The amount of venture capital under management in the US rose from around $4 billion in 1980 to $34 billion in 1990, declined slightly in the early 1990s, but then rose more than sixfold, from $35 billion to more than $234 billion, between 1994 and 2000 [National Science Board, 2002, 6-35]. Most recently, the spectacular growth of the Internet (which was followed by an almost equally spectacular fall) depended heavily upon venture capital financing.

American venture capital firms, it should be emphasized, have done a great deal more than merely supplying capital to high risk, high tech enterprises. They have in fact reshaped the nature of entrepreneurship by providing various kinds of sophisticated expertise and decisionmaking abilities that have prepared it for entry (and survival) in highly competitive markets. Indeed, in a very serious sense, American venture capital firms have been serving, not just as suppliers of risk capital, but also as suppliers of entrepreneurial talent.

IV

Thus, in a variety of ways, the history of western capitalism has involved the gradual introduction of a large number of legal and institutional innovations that had

the effect of expanding the commitment of resources to the pursuit of technological change. It achieved this by reducing, or limiting, the extent of financial risks associated with technological innovation. Risk reduction also meant an increase in the willingness to experiment, using this term in the broadest sense. Experimentation has taken place, not only with respect to new technologies, but with respect to new forms of business organization, of which the venture capital industry is an excellent example. A main virtue of western capitalism is that it has encouraged a search for new technologies on a decentralized basis, and with multiple sources of decisionmaking and risktaking, through anti-monopoly legislation.

As it happens, some of the most distinctive virtues of the capitalist form of organization have become apparent only as a result of examining the pathology of socialist societies that emerged in the course of the twentieth century. Indeed, one might say that the largest, unintentional experiment of the twentieth century was the experiments with organization, and associated incentives, that were undertaken under centralized socialism. I use the term “unintentional” because, although socialism and communism were identified as ultimate goals by large, powerful, political movements, the manner in which such societies would organize their economic activities had never been systematically thought through before the Bolshevik Revolution - certainly not by Karl Marx. These experiments have revealed, not only the defects inherent in the forms of centralised planning that were eventually adopted, but also the considerable strengths of market economies that had previously been insufficiently appreciated.

It has turned out, for example, that one reason why socialist societies have been so technologically backward is because both their central planners and their plant managers have been strongly risk-averse with respect to the introduction of new technologies. The Soviet planning system was relentlessly short-term in its outlook**.** Within the rules of the central planning game, plant managers had good reason to be risk-averse. But this risk aversion translated into an unwillingness to adopt new technologies, because the inevitable disruptiveness of installing new technologies would be likely to bring with it a failure to meet annual production quotas. And, for a plant manager, failing to fulfill the annual production goal of his plant, as laid down by the central planners (Gosplan), was likely to mark the abrupt end of his managerial career. But there was also a “Catch 22.” In the event that a new, productivity-increasing technology did get installed within a firm, the evidence of that expanded productive capability would be likely to be translated into a higher output quota for the innovating firm in subsequent years. Thus, for the plant manager, there was no gain.

There was, of course, much more to the story than that. After all, in certain fields, the Soviet Union had, without any question, some of the world's most brilliant scientists ("Blackboard sciences"). But the links, in terms of organization and incentives, that might connect scientific research with the development of improved technologies, and the firms that might eventually introduce those technologies into the market place - these were almost totally neglected (except for the military and space programs). As both the Russians and Chinese have eventually discovered, it is very difficult to make socialist economies more innovative without, at the same time, also making them more capitalistic.

The Soviet planners, in addition, suffered from a form of Gigantomania. Bigger was always regarded as better. And yet, in the successful economies of the West, small firms, and even single individuals, have always played roles of considerable importance in the process of technological innovation, and continue to do so. The freedom to experiment with firms of different sizes has been an ongoing phenomenon in capitalist economies. The freedom to experiment and to establish new firms has been of even greater importance when those freedoms have been connected with the enticing possibility of capturing large profits through the introduction of new or improved products. Indeed, the inducement effects of such prospective profits have been, without question, one of the great engines of capitalism's technological energy and dynamism. In reasonably competitive markets it has been true not only to say that innovation is risky, but that the **failure** to innovate, a willingness to remain with an increasingly outmoded technology, may turn out to be even more risky. Marx understood this point extremely well, and emphasized it quite forcefully..

Furthermore, the outcome of decentralized experimentation in capitalist societies, and the prospect of large profits, has been a highly diversified set of industrial structures. In the US, large firms totally dominate some sectors of the economy, firms of medium and small size persist elsewhere, and, still elsewhere, a small number of large firms coexist with a large number of small ones (Silicon Valley). Countries that have provided an environment of strong financial incentives for innovative activity may find that they have acquired certain comparative advantages in innovative activities that simply defy explanation in terms of the economist's intellectual toolkit. As Assar Lindbeck once pointed out: "...nobody could possibly have predicted, say at the turn of the twentieth century or a few decades later, that Sweden would be successful in the production of ballbearings, safety matches, cream separators, automatic lighthouses, telephone exchanges and military

airplanes - or, for that matter, pyramid-shaped packages for milk and marketing systems for furniture produced in Eastern Europe."

V

A great virtue of private property is that private firms, in undertaking research for new technologies, are very much aware that they confront huge uncertainties in the investment process, uncertainties that, as I have suggested, are generated by a wide variety of sources in a market economy. Private firms are also aware that they must make their own assessments of possible directions of research, and that they must "place their financial bets" accordingly. Bad bets are, of course, common; indeed, they are far more common than good ones. It is therefore tempting to conclude, as socialist planners have long concluded, that the manner in which competing firms pursue innovation, under the capitalist rules of the game, is a very wasteful process. But the notion that central planning and centralization of decision-making are likely to be more efficient than the decentralized market, turns out to be precisely the **opposite** of the truth when there is a high degree of uncertainty and when goals and objectives cannot be clearly stated ex ante.

Indeed, a considerable virtue of capitalist institutions is that, in the face of huge ex ante uncertainties concerning the possible uses of new technological capabilities, market forces provide strong financial incentives to explore along a wide variety of alternative paths [I would remind you of some of the eventual applications of the laser]. This wide-ranging exploration, by a large number of decentralized decisionmakers, is especially desirable in the early stages of research, when uncertainties are particularly high and when individuals with differences of opinion need to be encouraged to pursue their own hunches or intuitions.

These differences of opinion are often based on differences in access to information, especially on the part of individuals coming from different educational backgrounds or from different, earlier industrial experiences. Chemical engineers, for example, might be expected to approach the causes of unreliability, in the performance of transistors, in a very different way from electrical engineers or solid state physicists. Indeed, it is important that the general point should be stated more affirmatively: the achievement of technological progress, in the face of numerous uncertainties, absolutely **requires** such differences of opinion, in addition to a willingness to commit time, energy, and financial resources to support those differences of opinion. In fact, the freedom to pursue alternative paths of research, within a property rights regime that may provide substantial financial payoffs to

successful innovators, has been the driving force underlying the technological dynamism of western capitalism.

As I have argued, capitalist institutions, over the years, have developed a variety of ways of reducing the uncertainties, and therefore reducing many of the financial risks, that are associated with conducting research for improved technologies. However, the **end results** of that research necessarily remain unpredictable. After all, if we could correctly anticipate the eventual findings of a protracted and costly research process, then it would no longer be necessary to undertake that research in the first place. But that is precisely the point: we cannot so predict. No one in 1961 could have confidently predicted the wide range of eventual uses of the laser. And, I strongly suspect, no one today can predict the specific, future useful applications of nanotechnology or stem cell research. These applications cannot be captured through purely abstract reasoning or mathematical model building, however sophisticated. One simply has to explore the consequences of different trajectories of scientific research and technology development. A society that attaches a high value to economic growth needs to have a property rights system that will offer substantial financial rewards to those who are prepared to deal with the persisting uncertainties that are inherent in the innovation process.